STEELE GLACIER SURVEYING PROGRAM, YUKON, CANADA

1974 AND 1975

FIELD REPORTS TO PRINCIPAL INVESTIGATOR

SURVEY DATA

PRELIMINARY ANALYSIS

Submissions to Principal Investigator,

G. K. C. Clarke
Department of Geophysics and Astronomy
University of British Columbia
Vancouver, B.C., Canada

by Survey Party Chief,

Sam G. Collins
927 Military Avenue
Council Bluffs
Iowa 51501

To the Principal Investigator, G. K. C. Clarke:

PRELIMINARY REPORT OF 1974 FIELD GLACIOLOGICAL PROGRAM

Sam G. Collins, Party Chief

This report concerns field work performed between 27 June and 27 August, 1974, in the Steele Glacier area, St. Elias Mts., Yukon Territory. The four glaciers on which work was done are, specifically, Steele Glacier (Canadian Glacier Inventory number 4*9CAJ048), Rusty Glacier (#4*9CAJ091), Backe Glacier (#4*9CAJ092), and Trapridge Glacier (#4*9CAJ093).

The field party included, in addition to the Party Chief, three assistants: Mr. Tim (Dexter) Tight, 2744 Steiner Street, San Francisco, California 94123; Mr. Mark Smith, 114 Tyringham Road, Rochester, New York 14617; and Mr. Mark Berkstresser, R.R. 1 Box 180, Monte Vista, Colorado 81144. Many thanks are due these three young men, who worked hard and skillfully in the project's interest, without the customary inducement of salary; it is very largely to them that credit for the accomplishment of the summer belongs.

In addition to the Principal Investigator's grant funds through the University of British Columbia, support for the project was provided by the Arctic Institute of North America in the form of equipment, logistic assistance, radio service and field rations; Dr. W. A. Wood generously provided additional helicopter time; Mr. Berkstresser's expenses and travel were provided by scholarship grants from the Boy Scouts of America and the Explorers Club of New York.

HAZARD LAKE MAPPING AND BATHYMETRY:

Work was begun on the Hazard Lake mapping program immediately on arrival in the field, 2 July, and finished 7 July. It is of passing interest that the lake was still about 80% ice covered at our first sight of it, but after three nights of light rain and sunny days it became essentially free of ice, except for large bergs that continually formed by calving off from the glacier ice-dam. Ice gave no serious impediment to the sounding or mapping operations.

A plane table map of the lake perimeter was prepared first. For convenience in mapping, a scale of approximately 1/4800 was selected. Two plane tables at opposite ends of base lines were employed for rapidity and all map points were determined by the intersection of lines simultaneously observed at both instrument positions to identical targets. For the bathymetry, an inflatable canoe was used and line soundings were made at 90 data points more or less randomly distributed over the lake area. Two "handi-talky" radio sets proved invaluable in this operation, as it would have been extremely difficult, without them, for the boat operator to let the two surveyors know exactly when they were to record his position.

The data obtained permit construction of a bathymetric contour map with 5m contour intervals. In general, it shows that the lake, oriented more or less east-west, deepens rather regularly from the mouth of Hazard Creek (at the west end) eastward toward the ice dam. The maximum depth sounded was 38.7m. Because of danger from the calving ice-face at the east end of the lake, an imposing vertical wall 15m to 30m high, we did not approach it closely; depths greater

than ca 40m shown on the map by dashed contours are based on reasonable extrapolation and consideration of land-surface slope shown on small scale pre-surge maps of Steele Valley. Volume of the lake calculated from the map should be reasonably accurate, at a guess no further in error than 15%.

Since 1968, by which time very little motion persisted in the Steele Glacier ice against which Hazard Lake waters are impounded, an arcuate embayment of considerable size has developed by calving of the stationary glacier ice into the lake. With each subtraction of ice from the glacier dam, not only does the lake become larger in area, but (presumably) deeper as well, and thus greater in volume. It is reasonable to suspect that the lake may drain catastrophically if this process continues to the point where hydraulic head at the more-and-more deeply submerged glacier bottom comes to equal, or exceeds, the static head of the ice column forming the dam. It is of obvious interest to know the volume of water that is potentially injectable into Steele Creek and the Donjek River in the few hours of a glacial lake outburst. It is also intriguing to speculate on the possibility of forecasting the date of a potential outburst; this would certainly require a reliable estimate of the rate of retreat of the calving ice front and reliable knowledge of the topography of both the valley bottom downstream from the lake and the glacier surface in the same area. Figure I is the map.

STEELE GLACIER:

In preparation for future geophysical investigations and to facilitate precise monitoring of glacier movements, an array of 19 survey targets was deployed on the glacier surface. Twelve targets

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<u>STEELE GLACIER</u>

In preparation for future geological inv
facilitate routine monitoring of glacier
survey targets was deployed on the glacier

were placed in line, about a kilometer apart, more or less along the midline of the glacier and below the firnline; seven other targets were deployed in two cross-glacier traverses. The positions of all but two of the targets were determined by surveys.

The targets were designed to be free-standing, requiring no drilling. Each is a tetrapod constructed of two 20 ft x 3 in aluminum pipes, each bent through an angle of ca. 110°, secured together at the bend by a 1/2 in steel bolt. The tetrapods are strong enough to support three men, stand on any surface with one leg erect, and form a distinctive target about 13 ft high. We found them fairly easy to fabricate, rather difficult to transport, very easy and quick to assemble on the ice, and relatively distinct and easily seen through the telescope of the surveying instrument. Twenty were prepared, but one was lost when it broke its lanyard and fell from the helicopter. One was damaged in a similar fall from altitude, but it was salvaged and set up jury-rigged. Another was set up jury-rigged because its bolt was missing, but it can be erected properly in the future. I believe the design to be basically practical. Initial fabrication of forty leg units (bending and drilling) cost us most of one working day at Basecamp, but posed no serious problems. The leg units were carried to Burwash and flown from there to the glacier by helicopter; this did pose difficulty. The shape of the units makes them aerodynamic and very awkward to fly with; they have a strong tendency to oscillate and windmill at speeds greater than about 20 mph. In future, an effective vane should be fixed to the loaded legs to hold them straight in flight. At the glacier, we initially unloaded the legs in two caches, planning to distribute them and set them up on foot. We

1 and 2, were not surveyed, mostly because of the foul weather that affected the last week of our stay in the field. This lack is more serious, because it means one year's movement data cannot be gotten. It should be no great problem to survey the two lower targets next year. Survey results are being processed currently.

At two of the target sites, we were able to drill 16m holes and emplace in each a length of 1/8 in steel cable to serve as a reference against which ablation can be measured, permitting determination of vertical ice motion as well as horizontal. It was planned to emplace such an ablation reference at each of the midline targets, but this was given a low priority, left till last, and then not done because of bad weather.

RUSTY - BACKE - TRAPRIDGE GLACIERS:

The period between 1 and 16 August was spent resurveying and servicing established target arrays on these three small glaciers. Both exhibited much more extensive snowcover and lower firnlines than usual.

Rusty Glacier was last surveyed in the summer of 1971, at which time 56 targets were standing. Three years later we found 42 targets still erect and observable, a surprisingly high survival rate considering that there was no servicing of the targets at all in the interval. Few of the missing targets seem to have been buried; most of those lost were in the ablation zone and melted out. A very low accumulation rate is implied, and that only in the uppermost part of the cirque. Extensions were installed on eight targets and four were shortened. All targets appeared very close to the positions predicted for surveying purposes, strong evidence that no part of the

glacier has changed its rate of flow significantly.

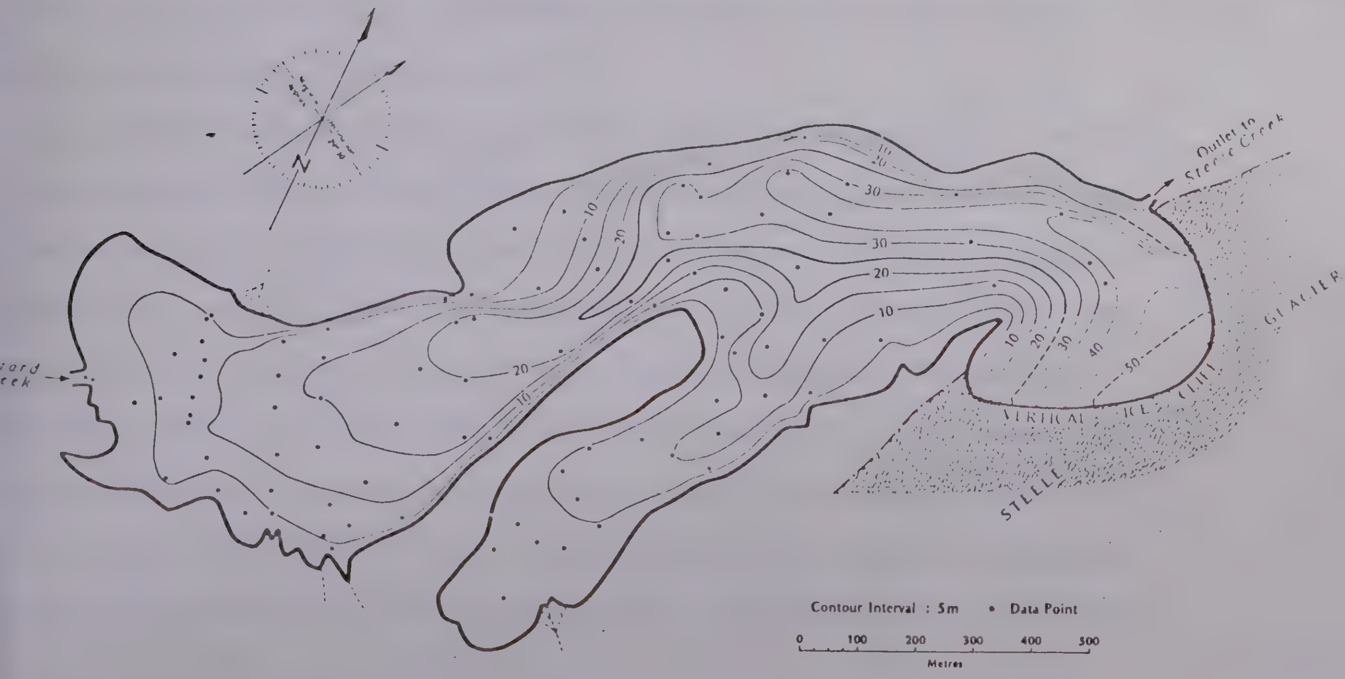
There have been no targets on the Backe Glacier since 1968. Two were installed this year, well up on the surge tongue, below the snowline. They are short surface tripods and will serve only for measurement of horizontal motion, but may yield some useful information.

Twenty five targets were observed on the Trapridge Glacier in 1974, eight less than were seen in its last survey in 1972. No obvious evidence was noted of accelerated motion on the Trapridge, although a number of predicted pole positions did not match observations. Snowcover was unusually heavy and widespread, however, and could have concealed considerable new crevasse development.

Computer processing of survey results is in progress.

"Hazard" Lake Bathymetry

Figure 1.



STEELE GLACIER SURVEYS, 1974 and 1975

REPORT OF SURVEY RESULTS

SAM G. COLLINS
827 Military Avenue
Council Bluffs, Iowa 51501
712-323-0659

Sam G. Collins, Party Chief

Assistants: Tim Ahern, Peter Cary

Surveying of targets on the ice of Steele Glacier in 1975 was accomplished between 28 June and 5 July, inclusive. This work recovered targets placed and surveyed between 9 July and 29 July of 1974. The 1974 survey results are incorporated into this report, although the work has been previously reported upon in greater detail.

Surveying in 1975 was restricted to the Steele Glacier itself and "Hazard" Lake (an unofficial name applied for use in this report only), immediately adjacent to the glacier. Only the data pertinent to these areas from the 1974 surveying is presented again in this report.

Target condition was generally acceptable, although considerably more target damage was sustained during the winter than had been anticipated or hoped for. Of the 19 targets originally deployed, Nos. 1 and 2 (not surveyed in 1974 either) could not be located; they may or may not remain undamaged, but are too distant from the observation stations occupied to be seen; all the rest were observed and located, including No. 12, which was not located in 1974. Nos. 6 and 10E were not properly erected originally and have collapsed. Nos. 3, 4, and 5 have lost the

upright element, probably because of wind vibration and breakage at the bent join with the other legs; the lower tripod remains intact in these cases and is easily observed. Nos. 9 and 10F have collapsed completely, but are still fairly easy to observe; the location of these targets is suspect, since they may have experienced a few meters of local motion in finding a new arrangement of rest on the ice surface. The remaining ten targets were erect and apparently in good order. Because of limitations of time and terrain, no repairs were undertaken. Most of the targets should be visible for some years, even without repair, although accurate aiming information will be required to locate the ones with least mechanical integrity.

Observations were made from the same two groups of stations (Instrument Positions) located and monumented in 1974. The "B" stations, located near M&CE Station 67A206 and oriented by reference to it (74B1, 74B2, 74B3, 74B4, ST206) were originally assigned coordinates computed from known Universal Transverse Mercator positions; these coordinates probably correspond with good precision to the UTM grid; no more than a few seconds of rotational error nor ± ca. 5cm translational error should occur. The "A" stations are less accurately determined; in 1974 they were assigned coordinates on an arbitrarily oriented grid for lack of accessible UTM references. Additional reference observations in 1975 permitted rotation and translation of the arbitrary coordinate system to fairly good correspondence with the UTM grid; disagreement larger than ca. 1.5m is unlikely (for stations 74A1, 74A2, 74A3, 74A4). Within both groups, stations

are located with respect to each other within error limits smaller than 2 or 3cm. Tables I and II give Instrument Position data for both 1974 and 1975.

Horizontal Position and Movement of Steele Glacier Targets:

Tables III and IV present all coordinates determined for Steele Glacier targets in 1974 and 1975. Several minor deficiencies should be noted: a) the fuel drum marking the 1973 site of geophysical drilling could not be found in 1975; b) Target No. 12 was not determined in 1974 so annual motion cannot be computed; c) the location given for Target No. 11 is almost certainly in error either in 1974 or 1975; because this target can be seen from only two stations, no cross-check is possible to decide which determination is incorrect; d) Target No. 8 is determined by sight-lines intersecting at very small angles and the target is more distant from the stations than average, also its line of motion is parallel with the long axis of the "ellipse of error," so that unreliability of motion determination in this case is unusually large; little weight should be given to either movement or strain rate measurements involving the apparent change in position of this target. In all other cases, accuracy seems to be good and probable errors generally smaller than ± ½m to 1m.

Table V summarizes measurements of all target motions in the interval between the two surveys. Horizontal movement in the area observed appears to be generally less than 5m; targets 7, 8, and 10E exceed this by amounts probably significant in

terms of general measurement accuracy, but the special case of No. 8 has already been discussed. No reason to doubt the other determinations can be found in the survey analysis. The large apparent motion of No. 11 is suspect, as previously mentioned, but could be real, in consideration of the fact that this target is directly across from the Hodgson Glacier and could be influenced by residual motion from that source. The traverses across the glacier at positions 4 and 10 exhibit the pattern of greater motion nearer the glacier midline expected in normal plastic flow of valley glaciers.

Casual inspection of movement data in Table V reveals a general trend (expected) of decreasing movement down-glacier. The data appear adequate for at least a rough analysis of longitudinal strain rates: these are presented in Table VI. Strain rates are consistently small and positive (compressive) with the single exception of the measurement between targets 8 and 9; the anomalous extensive value here reinforces suspicion of the measurement accuracy of Target No. 8, as no other explanation is immediately obvious. No clear trend of increasing or decreasing strain rates emerge from the data. It seems clearly justified to conclude, however, that the general pattern of strain rate throughout the targeted portion of the glacier is compression at 1 to 3×10^{-3} yr^{-1}.

<u>Vertical Movement of Steele Glacier Targets</u>:

Deviations from the mean of individual target altitudes measured in each set of observations generally average ca. 0.2m

or less throughout the survey and consistency of vertical measurements between years seems good; accuracy can be considered generally better than ± 0.2m probable error. Apparent vertical motions obviously attributable to loss of the target's top 3.05m leg, or to collapse of the whole 4.15m tetrahedral structure onto the ice surface have been corrected out of the results appearing here. Because of the small surface slope of the glacier and the small horizontal motion encountered, vertical movements attributable to the downhill component of glacier flow are probably smaller than measurement error and are not considered.

Tables V and VII show vertical target motion and estimated ablation through the surveyed area. Target No. 11 is not considered, because of the probability of inaccurate measurement. The data are taken to reflect ablation of ice from the glacier surface, upon which the targets rest, and some possible small residual melting-in of the target legs. This last amount is believed to be small, no more than 0.10 to 0.20m; the target legs characteristically melt into the ice by about 0.3m, and most of this settling had been accomplished before the initial survey, as all targets had been standing one to three weeks before observations began.

The data show a clear trend of increasing downward target displacement with time in the down-glacier direction, expected as ablation should increase in that pattern. In Table VII the data have been smoothed by a three-point running average to yield a completely regular trend; it is believed that this

is a valid reflection of the trend in ablation.

Under the heading "Estimated Ablation" in Table VII, two correction factors of opposite sign have been added (algebraically) to the running average values: a) possible settling of the target legs into the ice has been allowed for by adding +0.15m to the values, and b) -0.30m has been added to account for the vertical component of glacier flow. This last correction factor was arrived at as follows: assuming that linear compression at the average rate of 1.14×10^{-3} yr^{-1} affects the equivalent of the upper 200m of the glacier ice, then any vertical column of ice must be extended upward by $200m \times 1.14 \times 10^{-3}$ each year to conserve mass, or, the glacier surface would rise by ca. 0.3m annually, disregarding ablation, as a result of the glacier's small ice flow. Both of the above corrections are small and partially cancel, both are necessarily rather arbitrary estimates; since they affect the results relatively little their inclusion is probably of small significance. The ablation estimates are considered to be reasonably valid as general values for the measured portion of the glacier.

Observations of "Hazard Lake":

A recognizeable rock in the outlet channel of the lake was intersected from the "A" stations to yield the altitude and UTM coordinates. The lake surface altitude obtained is 1674.6m (MSL) and the coordinates of the outlet are E 543372.5 N 6792309.8.

Six observations were made on the visible portion of the

cliff face of the lake's ice-dam. Some arbitrary judgement is involved in deciding just what constitutes the "top" of the cliff, a rounded and irregular feature at most points, but the measurements are fairly consistent and believeable: 26.31, 33.38, 32.14, 25.80, 27.70, and 37.20 (meters). The mean of these is 30.42m.

ALL ANGLES ARE GIVEN IN CENTESIMAL GRADS (400G CIRCLE).
VERTICAL CORRECTION FACTOR USED IS .0650 M PER HORIZONTAL KM-SQUARED.

1974 INSTRUMENT POSITION COORDINATES AND INSTRUMENT ALTITUDES. WITH COMPUTATION NUMBER AND HEIGHT OF INSTRUMENT

NO.	IP NAME	EASTING	NORTHING	ALTITUDE	H.I.
1	74A1A	542641.07	6790199.75	1925.05	1.34
2	74A2A	542622.84	6790149.60	1932.76	1.50
3	74A1B	542641.07	6790199.75	1925.20	1.49
4	74A2B	542622.84	6790149.60	1932.80	1.54
5	74A3	542595.24	6790025.12	1973.20	1.59
6	74A4	542638.00	6789989.50	1947.75	1.43
7	ST206	543826.64	6783005.14	2219.71	1.70
8	74B1	543798.36	6782997.10	2216.10	1.60
9	74B2	543926.33	6782814.19	2232.73	1.58
10	74B3	543982.07	6783684.42	2275.99	1.51
11	74B4	543771.39	6783424.22	2170.48	1.63
12	PYMDI	543861.04	6795390.58	2798.69	——

TABLE I

ALL ANGLES ARE GIVEN IN CENTESIMAL GRADS (400G CIRCLE).
VERTICAL CORRECTION FACTOR USED IS .0650 M PER HORIZONTAL KM-SQUARED.

1975 INSTRUMENT POSITION COORDINATES AND INSTRUMENT ALTITUDES, WITH COMPUTATION NUMBER AND HEIGHT OF INSTRUMENT

NO.	IP NAME	EASTING	NORTHING	ALTITUDE	H.I.
1	74R1	543798.36	6782997.10	2215.99	1.49
2	ST206	543826.64	6783005.14	2219.62	1.61
3	74R3	543982.07	6783684.42	2275.93	1.45
4	74R4	543771.39	6783424.22	2170.25	1.40
5	74R3	543982.07	6783684.42	2275.92	1.44
6	74R2	543926.33	6782814.19	2232.69	1.54
7	74A1	542641.07	6790199.75	1925.14	1.43
8	74A2	542622.84	6790149.60	1932.76	1.50
9	74A3	542595.24	6790025.12	1973.01	1.40
10	74A4	542638.00	6789989.50	1947.86	1.54
11	PYMDI	543861.04	6795390.58	2798.69	—

TABLE II

SUMMARY OF 1974 MEAN TARGET COORDINATES

	NAME	EASTING	NORTHING	ALTITUDE	DATE	PRECISION (0/00)
	~~874A4~~	~~542637.95~~	~~6789987.82~~	~~1947.67~~	~~28 7 1974~~	~~1 / 5.000~~
	3	545551.26	6791978.25	1706.10	20 7 1974	1 / 73.000
	4	544601.85	6791470.82	1738.39	19 7 1974	1 / 118.000
	4A	544048.15	6791305.46	1732.39	19 7 1974	1 / 43.000
	4B	543555.92	6791101.88	1742.96	19 7 1974	1 / 38.000
	4C	544942.53	6791313.19	1723.82	20 7 1974	1 / 44.000
	4D	545406.36	6791198.27	1734.20	20 7 1974	1 / 14.000
	5	544257.74	6789810.51	1751.86	21 7 1974	1 / 92.000
	6	544397.62	6788985.22	1795.57	21 7 1974	1 / 287.000
	7	544087.15	6788138.58	1796.04	21 7 1974	1 / 180.000
	8	543785.43	6786731.14	1827.15	21 7 1974	1 / 52.000
1973 Drilling Site	BPL3	544122.86	6791657.22	1729.88	19 7 1974	1 / 134.000
	9	543023.68	6784934.85	1895.38	27 7 1974	1 / 24.000
	10	542503.54	6782703.30	1945.48	27 7 1974	1 / 29.000
	10E	542243.00	6782473.13	1955.00	27 7 1974	1 / 66.000
	10F	542027.73	6782293.93	1942.70	27 7 1974	1 / 56.000
	10G	543005.54	6782763.13	1965.12	27 7 1974	1 / 25.000
	11	543128.31	6780849.58	1990.73	27 7 1974	1 / 10.000
		0.00	0.00	0.00	0 0 0	1 / 0.000
		0.00	0.00	0.00	0 0 0	1 / 0.000
		0.00	0.00	0.00	0 0 0	1 / 0.000

TABLE III

	NAME	EASTING	NORTHING	ALTITUDE	DATE	PRECISION (0/00)
	~~A1~~	~~542641.14~~	~~6790213.57~~	~~I~~	~~29 7 1975~~	~~1 / 10.000~~
	~~74A40~~	~~542633.30~~	~~6789989.47~~	~~1949.10~~	~~27 6 1975~~	~~1 / 5.000~~
	~~74J1P~~	~~543796.79~~	~~6792996.92~~	~~2212.50~~	~~2 7 1975~~	~~1 / 12.000~~
Tempest Peak	PYMD	543862.72	6795385.60	2800.64	30 6 1975	1 / 7.000
False Tempest Peak	EPMD	544629.43	6796708.25	2744.09	30 6 1975	1 / 7.000
Hazard Lake Outlet	GROCK	543372.48	6792309.78	1674.60	3 7 1975	1 / 13.000
	3	545548.74	6791978.14	1700.43	3 7 1975	1 / 85.000
	4	544602.19	6791472.01	1732.18	3 7 1975	1 / 41.000
	4A	544047.38	6791305.98	1728.97	3 7 1975	1 / 51.000
	4B	543554.47	6791100.82	1740.74	3 7 1975	1 / 43.000
	4C	544942.59	6791315.26	1722.74	3 7 1975	1 / 56.000
	4D	545405.83	6791197.97	1731.78	3 7 1975	1 / 57.000
	5	544256.19	6789814.36	1746.40	3 7 1975	1 / 62.000
	6	544394.30	6788989.38	1790.70	3 7 1975	1 / 47.000
	7	544083.39	6788146.11	1793.86	3 7 1975	1 / 837.000
	8	543783.38	6786741.39	1825.50	3 7 1975	1 / 79.000
	9	543027.60	6784935.09	1890.98	28 6 1975	1 / 16.000
	10	542502.91	6782707.37	1944.12	28 6 1975	1 / 20.000
	10E	542243.05	6782479.27	1950.23	28 6 1975	1 / 18.000
	10F	542027.68	6782297.73	1939.08	28 6 1975	1 / 15.000
	10G	543005.14	6782765.78	1963.10	28 6 1975	1 / 10.000
	11	543142.73	6780884.37	1993.81	28 6 1975	1 / 10.000
	12	543942.42	6779050.57	2016.10	28 6 1975	1 / 49.000
1975 Drilling Site	75BRL	544396.47	6775939.01	2143.17	28 6 1975	1 / 19.000

TABLE IV

STEELE GLACIER SURVEYS 1974 - 1975

Summary of Target Motion

TARGET NAME	HORIZONTAL MOTION (meters)	HORIZONTAL DIRECTION (degrees)	VERTICAL MOTION (meters)
3	2.52	270	-2.62
4	1.24	016	-3.16
4A	0.93	304	-3.42
4B	1.80	234	-2.22
4C	2.07	002	-1.08
4D	0.61	240	-2.42
5	4.15	338	-2.41
6	5.32	321	-1.82
7	8.42	333	-2.18
8	10.45	349	-1.65
9	3.92	086	-1.35
10	4.12	351	-1.36
10E	6.14	000	-1.72
10F	3.80	359	-0.57
10G	2.68	351	-2.02
11*	37.66*	023*	+3.81*

*Probably a large error

Target #12 was not observed in 1974

STEELE GLACIER SURVEYS 1974 - 1975

Longitudinal Strain Rates *

TARGET NAME	DISTANCES BETWEEN TARGETS 1974 s (m)	1975 s (m)	$\frac{\Delta s}{yr}$ (m)	$\frac{\Delta s}{yr \times s}$ x 10^{-3}
3 ----------				
	1076.51	1073.37	3.14	+2.92
4 ----------				
	1695.59	1693.38	2.21	+1.30
5 ----------				
	837.06	836.46	0.60	+0.72
6 ----------				
	901.77	898.76	3.01	+3.34
7 ----------				
	1439.42	1436.40	3.02	+2.10
8 ----------				
	1951.13	1958.04	-6.91	-3.54
9 ----------				
	2291.37	2288.68	2.69	+1.17
10 ----------				

Mean of Longitudinal Strain Rates in Study Area: $+1.14 \times 10^{-3}$ yr^{-1}

* Positive signed strain rates are compressive and negative extensive.

STEELE GLACIER SURVEYS 1974 - 1975

Average Vertical Trends

TARGET NAME	VERTICAL MOTION (m)	RUNNING AVERAGE (m)
3	-2.62	
4 (mean)	-2.46	-2.50
5	-2.41	-2.23
6	-1.82	-2.14
7	-2.18	-1.88
8	-1.65	-1.73
9	-1.35	-1.47
10 (mean)	-1.42	

Estimated Ablation

TARGET NAME	ABLATION ESTIMATE
3	2.77m
4 (mean)	2.65m
5	2.38m
6	2.29m
7	2.03m
8	1.88m
9	1.62m
10 (mean)	1.57m

(Corrected for target settling and compressive surface rise)

Values given show vertical meters of ice ablated between surveys, not corrected to water-equivalent.